Supplemental Material

Supplemental figures

Supplemental Figure 1. Model fit to simulated data. For any smoothly varying stimulus, the position, velocity, acceleration and jerk are correlated. It is therefore possible that a neuron driven by (say) acceleration may be fit by an integrate-and-fire model driven by position. On the other hand, position and acceleration can have widely differing contributions at different stimulus frequencies and may elicit differing patterns of spikes. To address this possibility, we simulated the responses of SA1, RA and PC afferents (using parameters previously estimated from specific afferents in the data). We thus knew in advance which quantities these simulated afferents responded to. We then estimated model parameters from these simulated spikes and performed statistical comparisons as shown in Figure 6. We found that the true underlying variables (the ones that were used to generate the data) could be successfully recovered from the simulated data using the approach described here. Each subplot shows the mean spike distance ($D_{\text{spike}}$) per spike for each of the 10 models for each afferent type derived from simulated data. In each case, we generated spike trains using SA1, RA and PC models, then fit each of the 10 models to the simulated data to ascertain which model best accounted for the measured spike trains. (A) For the simulated SA1 afferents, the best model was one with position and velocity as inputs. (B) For simulated RA afferents, a model with only velocity as input was as good as any other model. (C) For simulated Pacinian afferents, the position, velocity and acceleration model was as good or better than the other models.
Supplemental Figure 2. Rectification. Half-wave rectifying (A) and full-wave rectifying (B) SA1 afferent.

Left: Stimulus (black trace) along with the afferent response it evoked over five repeated presentations (red rasters). Right: Phase histogram. One neuron only responds during indentations whereas the other responds both during indentations and retractions. Spikes produced by the half-wave rectifying neuron are clustered within a single quadrant, whereas those evoked in the full wave rectifying neuron occur in two modes that are approximately 180° apart. Full-wave rectification could be a byproduct of a full-wave rectifying non-linearity or could be due to the neuron’s sensitivity to position and acceleration (which are 180° out of phase) combined with a half-wave rectifying non-linearity. The model accommodates both possibilities.
Supplemental Figure 3. Illustration of the position-sensitivity of PC afferents. The spike rasters show the responses of a PC afferent to a diharmonic stimulus with components at 5 and 100Hz. As can be seen in the figure, the low-frequency component strongly modulates the response to the high-frequency component. The low frequency component is almost completely absent in the acceleration trace, weak in the velocity, but very strong in the position trace. The low-frequency modulation of the response suggests that PC afferents are sensitive to position and/or velocity (in fact, they are sensitive to all three stimulus quantities).
Supplemental Figure 4. Saturation of neuronal responses. Rate-intensity and phase-intensity functions for a PC afferent (red points) at 40Hz along with the corresponding model predictions. The model overestimates the response of the PC fiber at high intensities because it does not account for saturation (the stimulus pre-filters are all linear).
Supplemental Figure 5. Predicted firing rates for SA1 afferents matched their observed counterparts over the entire dynamic range. Predicted RA responses matched observed responses over a range. However, predictions became much poorer for high intensity stimuli, likely reflecting the recruitment of additional Meissner corpuscles innervated by the same fiber. PC firing rates exhibited clear saturation, so the predicted firing rates strongly overestimated the responses to high-intensity stimuli.
Supplemental Figure 6. Example filters for a typical SA1, RA and PC afferent. Filters corresponding to positive (solid lines) and negative (dashed lines) are generally correlated (see below). Most filters tend to have low-pass or band-pass characteristics.